

Submarine Debris Flows and their Devolution to Turbidity Currents on the Continental Slope

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Award #: N00014-93-0300

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LONG-TERM GOAL

My long-term goals are to a) develop a mechanistic understanding of submarine debris flows and associated turbidity currents and b) incorporate this understanding into the broader context of the evolution of the morphology of the continental slope.

OBJECTIVES

Objectives can be enumerated as follows.

- Determine the mechanisms of submarine debris flow runout.
- Characterize the deposits of submarine debris flows.
- Characterize and describe tendencies for transition to turbidity currents.
- Develop models for predicting runout and deposition of submarine debris flows.
- Extract the essentials of submarine debris flow behavior for incorporation into models of continental slope dynamics, morphology and stratigraphy.

APPROACH

The approach of the research is primarily experimental and numerical. Three tanks are being used for the research a) the “Fish Tank,” a facility built especially for the study of submarine debris flows, b) the “Garcia Tank,” a facility originally built to study turbidity currents but adapted for submarine debris flows and c) the “Wide Tank,” a facility in which laterally unconfined submarine debris flows can be studied. The experimental research is constantly compared with the results of field studies by STRATAFORM and other researchers. The numerical models are developed with the aid of the experiments, and are being made available to other STRATAFORM researchers.

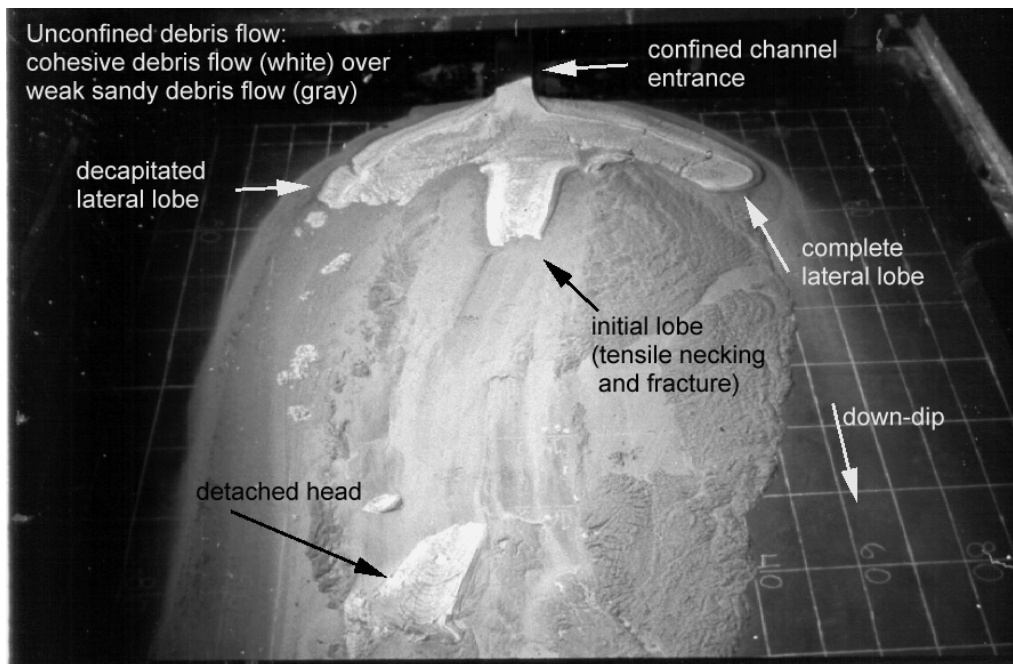
WORK COMPLETED

The following work has been completed

- Basic experiments characterizing the runout and deposits of 1-D submarine debris flows containing only sand and silt.
- Basic experiments characterizing the runout and deposits of 1-D submarine debris flows containing a clay component consisting of bentonite, kaolinite and illite.

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 30 SEP 1999		2. REPORT TYPE		3. DATES COVERED 00-00-1999 to 00-00-1999	
4. TITLE AND SUBTITLE Submarine Debris Flows and their Devolution to Turbidity Currents on the Continental Slope				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Minnesota, St. Anthony Falls Laboratory, Minneapolis, MN, 55414				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 4	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

- Basic experiments characterizing the runout and deposits of 1-D submarine debris flows with minimal fines content.
- Experiments on the transition of submarine debris flows to turbidity currents.
- Experiments on the development of submarine fans by stacked unconfined 2-D submarine debris flows.
- Numerical modeling characterizing the tendency for turbidity currents to channelize.
- Numerical modeling of submarine debris flows with Newtonian, Bingham and Herschel-Bulkley rheologies.
- Numerical modeling of hydroplaning submarine debris flows.
- Experimental research on basin filling by turbidity currents.



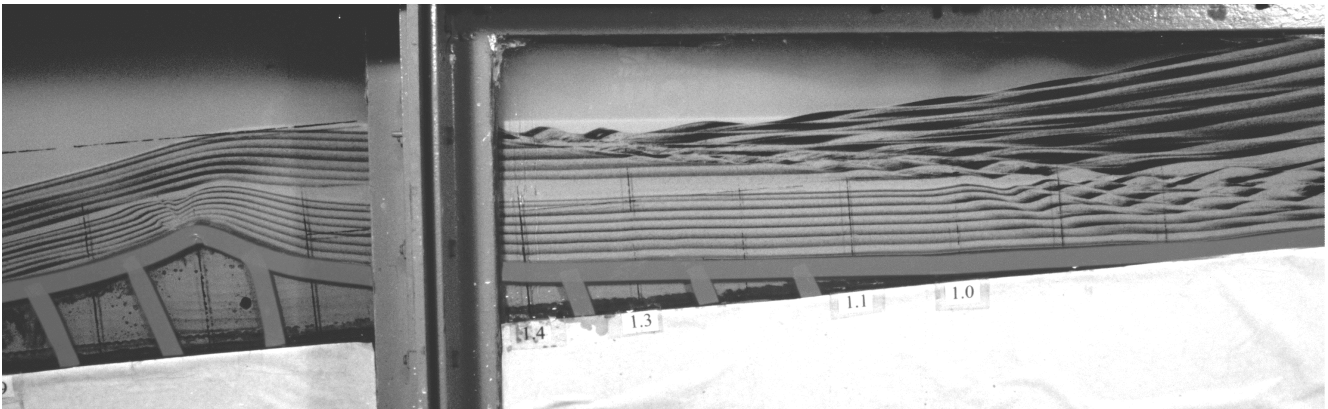
View of an unconfined submarine debris flow deposit over an antecedent deposit.

RESULTS

The research to date has established the following.

- The heads of submarine debris flows can hydroplane. This may offer an explanation for the long runout distances often observed in the submarine environment.
- As the head goes into hydroplaning, it can often accelerate away from the body, eventually self-decapitating. This offers an explanation for cases for which isolated debris flow deposits, i.e. “outrunner blocks” are observed far from the source area.
- Hydroplaning appears to suppress the ability of submarine debris flows to mobilize antecedent deposits.
- Active, mobile submarine debris flows can be sustained with a slurry of sand and as little as 1% bentonite or 7% kaolinite by weight. Experimental submarine debris flows cannot be sustained in the absence of fines.
- The deposit thickness of submarine debris flows can often be substantially less than that expected from the yield strength of the slurry.

- Runny slurries can often produce a pattern of normal grading in the deposit. Sticky slurries produce massive grading.
- The principles of distorted similitude can be used to scale up experimental results to field results within a realistic range.
- The process of filling of minibasins on the continental slope by turbidity currents can be successfully modeled in the laboratory.



View of the filling of an experimental minibasin by turbidity currents containing sand and coal.

IMPACT/APPLICATION

The research has provided a tentative explanation for the long runout distances of submarine debris flows. It has also helped explain the origin of isolated debris flow deposits. It has characterized the range over which “sandy debris flows” can occur. It has provided a picture of the mechanism by which secondary turbidity currents are produced. The work has led to numerical modeling of the process of hydroplaning, and had led to cooperative research on the development of numerical models of stacked debris flow deposits and stacked turbidites on continental margins. It has also provided information for the development of models of entire continental margins i.e. “whole-margin modeling.”

TRANSITIONS

The ONR-funded research has led to a cooperative effort with Mobil Technology Company on sandy debris flows. A cooperative effort with Prof. Anders Elverhoi of Oslo University, Norway has led to several papers pertaining to submarine debris flows on the Norwegian margin. Recent experiments on the filling of minibasins by turbidity currents represent a joint effort between STRATAFORM and the Experimental Stratigraphy Consortium of St. Anthony Falls Laboratory. DURIP has provided funds for extending the capabilities of the Experimental Stratigraphy facilities.

RELATED PROJECTS

There are several projects in ONR STRATAFORM which have ties to the present study. These include

- The work by the group led by J. Syvitski on margin modeling,
- The work by L. Pratson on modeling of stacked debrites and turbidites,
- The work by M. Garcia on depositional turbidity currents and submarine debris flows,

- The work by H. Lee and J. Locat on debris flow rheology,
- The work by M. Steckler on geometric modeling of margins,
- The work by D. Prior on submarine mass movements and
- The work by A. Niedoroda and C. Reed on the modeling of margins and turbidity currents.

In addition to the above, the following cooperation exists outside of STRATAFORM.

- Work with C. Paola, V. Voller and J. Swenson on 'whole margin modeling,
- Work with C. Paola on experimental modeling of margin stratigraphy,
- Work with A. Elverhoi on high-latitude margins and
- Work with G. Shanmugam on sandy debris flows.

PUBLICATIONS

Marr, J., Harff, P., Shanmugam, G. and Parker, G. 1999 Experiments on subaqueous sandy debris flows: the role of clay content on flow dynamics and deposit structure. Geological Society of America Bulletin, in press.

Pratson, L., Imran, J., Parker, G., Syvitski, J. and Hutton, E., 1999 Debris flows versus turbidity currents: a modeling comparison of their dynamics and deposits. American Association of Petroleum Geologists Bulletin, in press.

Imran, J., Harff, P. and Parker, G. 1999 A numerical model of submarine debris flow with graphical interface. Computers and Geosciences, submitted.

Harbitz, C., Elverhoi, A., Mohrig, A., Parker, G. and Dimakis, P. 1999 Hydroplaning of muddy debris flows: theoretical descriptions and applications on high-latitude glacial deep-sea fans. Journal of Geophysical Research, submitted.

Marr, J., Elverhoi, A., Parker, G., Imran, J. and Harff, P. 1999 Numerical simulation of mud-rich subaqueous debris flows on the glacially active margins of the Svalbard-Barents Sea. Journal of Geophysical Research, submitted.

Elverhoi, A., Harbitz, C., Dimakis, P., Marr, J., Mohrig, D. and Parker, G. 1999 On the dynamics of subaqueous debris flows. Oceanography, submitted.

Marr, J., Parker, G. and Harff, P. 1999 From debris flow to turbidity current: the transport and deposition of sand-rich subaqueous gravity flows. Journal of Sedimentary Research, in preparation for submission.